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Some Constraints on the Domain of Phrasal Resyllabification in French

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Abstract: This paper examines the French phrasal resyllabification process known as enchaînement 'linking' in the light of three recent proposals about connected speech phenomena and their relation to syntactic structure. It is based on a corpus illustrating linking consonants and initial consonants in minimal or near minimal pairs across different types of prosodic/syntactic boundaries. The sentences were read five times at three different speaking rates by two native speakers. The study shows that (1) with increasing rate of speech, the domain of the rule becomes larger, irrespective of prosodic structure, and (2) there exists a specific degree of disjuncture beyond which it does not apply in a given tempo. The study thus provides evidence that, at least in French, resyllabification belongs to the phonological rules proper, and not to the rules for defining (post-lexical) phonological representation. Research on phrasal resyllabification rules in other languages and based on a larger number of speakers is, however, needed before any generalizations can be made.

0. Introduction

One of the important issues in phonological analysis is the relation between surface syntactic structure and phrasal (postcyclic) phonology. In particular, recent debate has centered on the existence and the nature of prosodic structure, and its mediating role between syntax and phonology.

In Kaisse 1985 the syntax-phonology relation is considered to be direct, with syntactic structure feeding directly into word-external phonology without any intermediary (prosodic) stage. In Nespor and Vogel 1982, and Selkirk 1984, on the other hand, this relation is seen as an indirect one, mediated by a set of prosodic rules which interpret surface syntactic representation into phonological representation. The former consider this mapping process as resulting in a single hierarchical (accentual, intonational and sentential) prosodic constituent structure. The latter sees it as resulting in two distinct sorts of hierarchical organizations, namely prosodic constituent structure as just described, and rhythmic structure, that is, the alignment of syllables with a metrical grid. The grid corresponds to a series of levels consisting of a sequence of positions (or beats) which stand for points in time and "define the recurring temporal periodicities of rhythm" (Selkirk 1984:7).

Both of the latter models also differ from Kaisse with respect to their predictions about the effect of prosodic structure on phrasal phonological rules. Nespor and Vogel claim that particular rules are restricted to particular prosodic (accentual, intonational or sentential)

domains. Selkirk contends that connected speech rules (but possibly not phrasal resyllabification rules) are sensitive to rhythmic structure, and that prosodic, that is, mainly intonational structure, is important only in so far as it affects the realization of the metrical grid. More specifically, phrasal rules are said to require some degree of adjacency in time which is defined with respect to a certain number of so-called silent grid positions. These positions represent varying degrees of rhythmic disjuncture, and are introduced on the basis of syntactic structure by a rule of Silent Demibeat Addition (Selkirk 1984: 313ff).

One factor that plays a role in all three models is rate of speech. Kaisse distinguishes between two types of connected speech phenomena, depending on their sensitivity to tempo: so-called rules of external sandhi which are affected only by syntactic, lexical and stylistic factors, and so-called fast speech rules which are said to be sensitive only to rate of articulation and to apply across the board, that is, across any structural boundary. Nespor and Vogel (1982:234, 239) subsume rate of speech under a constellation of extra-linguistic factors also including style, constituent size and presumably others, which are assumed to bring upon restructuring of smaller prosodic units into larger, more inclusive ones and thereby account for a certain amount of variability in phrasing.

In Selkirk such variability follows from the fact that prosodic structure is freely assigned to the surface structure of an utterance, resulting in more than one possible prosodic representation subject to a well-formedness condition. The assumption with respect to rate of speech is that for any tempo a real-time value is assigned to individual grid positions, and the faster the tempo, the shorter the real-time duration of the grid position. With any phrasal rule there is associated a specification of the real-time adjacency it requires, say n msec. for rule x. It follows that with increasing tempo, the domain of such a rule is expected to be extended, since it will take more silent grid positions to reach n amount of real-time. This approach to disjuncture does not therefore require any changes in the formal representation with changes in tempo.

Surprisingly, all three models use a number of identical phonological rules such as raddoppiamento sintattico in Italian, French liaison, American English flapping, as illustrative and corroborative examples. The first is a resyllabification rule which accounts for the lengthening of the initial consonant of the first word in a sequence of two words, under certain phonological and syntactic conditions (e.g. parlo[b]ene --> parlo[b:]ene, 'he spoke well' (Nespor and Vogel 1982:227). The second refers to the syllabic association of an otherwise unpronounced (so-called 'mute') consonant with a following vowel-initial word, as in petit ami 'boyfriend' /pətit ami/ --> [pə-ti-ta-mi] vs. petit tamis /pətit tami/--> [pə-ti-ta-mi] 'small strainer', where hyphens represent syllable boundaries. The third is a phonological rule which is contingent upon previous resyllabification (more specifically, ambisyllabification) of consonants with unstressed initial vowels in following words, and which reduces ambisyllabic alveolar stops to voiced flaps, as in get a pen /gɛt ə pɛn/ --> resyllabification: /gɛtə pɛn/ --> flapping: [gɛDəpɛn], with the ambisyllabic consonant underlined. All three rules thus have in common the fact that they involve resyllabification. Given the fact, however, that the conceptual differences between the three proposals lead to very different

empirical predictions, one would not expect identical rules to concurrently support all three proposals. It seems therefore that a closer look at connected speech phenomena, based on experimental evidence, is in order to evaluate these three theories.

The present study is a first step towards such an empirically based examination of phrasal rules. It investigates the influence of the three factors (1) rate of speech, (2) degree of disjuncture and (3) prosodic structure on the domain of French enchaînement ('linking'), in light of the three proposals just summarized about connected speech phenomena and their relation to syntactic, and prosodic or rhythmic structure.

Enchaînement, that is, the phrasal resyllabification of a word-final 'nonmute' consonant with the following vowel-initial word as in petite amie 'girlfriend' [pə-ti-ta-mi], is examined here rather than liaison, because it truly exemplifies resyllabification of consonants from one syllable to another, while liaison technically speaking does not. Recent autosegmental analyses of final consonants in French posit underlying extra-syllabic final consonants, that is, consonants which are not associated with any syllable. In the course of the derivation, such consonants are either syllabically integrated into the preceding word by a morphological rule such as feminine formation, and later (in postlexical phonology) resyllabified with the following vowel-initial word (enchaînement); or they are integrated by a phrasal phonological rule (liaison) into the following word if it begins with a vowel, and remain otherwise extrasyllabic, that is, are phonetically unrealized (e.g. Encrevé 1983, Clements and Keyser 1983).

After exposing the insufficiency of previous studies on French enchaînement with respect to rate of speech, syntactic disjuncture and prosodic structure, an analysis of the French prosodic system based on recent phonetic work is sketched out in section 2. The experimental design of the experiment is outlined next with a list of the (syntactic and prosodic) contexts and the corpus, followed by the description of the data analysis with respect to a number of phonetic cues. The results are presented in section 5. They focus on the presence or absence of a pause following the relevant linking consonant, the occurrence or nonoccurrence of prosodic restructuring of the phrases on either side; the phonetic realization of the consonant; and various duration measurements which provide evidence for syllabic structure, namely the duration of the linking consonant, of the preceding vowel, and the formant transitions leading form the consonant to the vowels on either side. The discussion centers around the effects of tempo in its interrelation with syntactic and prosodic structure. It is shown that only Selkirk's model makes the right predictions, namely that (1) the domain of the French resyllabification rule becomes larger with increasing rate of articulation, irrespective of prosodic structure, and (2) that there exists in a given tempo a specific degree of syntactic disjuncture beyond which it does not apply.

1. Existing Studies on Enchaînement

Whereas there exist many studies of the various (syntactic, prosodic, stylistic, sociolinguistic, etc.) constraints on French liaison, enchaînement has received much less attention by linguists. A thorough examination of existing phonological and phonetic descriptions of French

reveals merely a few references to some stylistic and potential prosodic constraints.

The stylistic constraints rest on a difference between normal connected speech and a very explicit and conscious style of speech in which enchaînement can be suspended, mainly to fulfill a disambiguating function, or as a means for contrasting and emphasizing, that is, intentionally isolating (Malmberg 1964:117ff.). Based on experimental studies by Grammont 1933 and Durand 1939 who recorded oral air pressure and "glottal tension" on oscillograms and with the help of other machinery, the difference between initial and linking consonants in monitored speech is said to correspond to a difference in articulatory tension, that is, contraction of the vocal tract muscles (in particular, the laryngeal muscles). Initial consonants are said to be articulated with increasing tension, and linking consonants with decreasing tension (see also Delattre 1940).

The rare references in the literature to the prosodic domain of enchaînement are not experimentally backed and reveal divided opinions. Older descriptions of French, such as Vidon-Varney (1933:141), suggest that enchaînement usually occurs between what she calls rhythm groups, and sometimes even between what she calls breath-groups, an opinion which is shared by Pernot (1937:337): "Que ce soit à l'interieur d'un groupe rythmique ou d'un groupe à l'autre, à condition que l'émission de voix ne cesse pas, l'enchaînement est toujours possible et même désirable". In more recent descriptions, it is suggested that enchaînement takes place only within rhythm groups (e.g., Léon 1966:118). Similarly Pulgram 1965, 1970, defines rhythm groups as the smallest units of utterance within which word boundaries are segmentally and suprasegmentally obliterated, and which are demarcated by oxytonic stress and bounded by disjuncture, thereby implying the absence of resyllabification across such units. The two prosodic domains referred to in these works are discussed in the next section.

2. The French Prosodic System

Investigators of French prosody agree that the prosodic parameters operating in the language, namely fundamental frequency (henceforth, Fo) and phrase-final lengthening, divide longer sentences into at least two hierarchical levels of prosodic units (e.g., Di Cristo 1975, Martin 1980, 1982, Vaissière 1974, 1975, 1980, Delgutte 1978).

The first level unit is the breath-group.[1] Its boundaries are signaled by a variety of phonetic cues, including those listed in (1) outlined in Vaissière (ibid.).

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[1]There exist a wealth of different terms for the prosodic units in French, and the use of a same term by different researchers to represent a different unit and different terms to represent the same unit adds to the confusion. In the present study the terms breath-group and rhythm group are used for, respectively, the first and the second level units. They correspond roughly to Nespor and Vogel's intonation and accentual phrases and will both be subsumed under the term prosodic unit when a differentiation between them is unimportant for the discussion at hand. Furthermore, the term stressed syllable will be used to refer to the prosodic unit-final syllable.

(1) 1. a resetting of the baseline;
2. the presence of a rising contour at the beginning of the last word of a nonsentence-final breath-group, followed by a fall and terminated by a rising contour at the end of the word (= Vaissiere's P1 pattern); or
3. a rising-falling movement on the last word of a sentence-final breath-group (pattern P4); and
4. frequently, surrounding pauses.

The second level unit is the prosodic word or rhythm group (see note 1), with rising intonation at the onset of the final word which is sustained or gradually falls until the peak (sharp rise followed by lowering) on the last syllable (pattern P2). These Fo patterns and one additional pattern found exclusively within rhythm groups (pattern P3) are shown in Fig.1.[2]

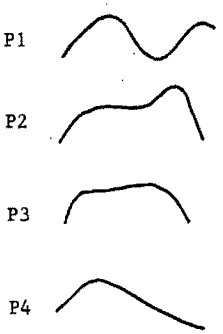

Fig.1: The four patterns characteristic of the Fo contours of French (adapted from Vaissière 1975).

These patterns are mostly co-occurrent with content words of three syllables or more. Shorter words often reveal a simpler, incomplete pattern, or share a pattern with the preceding and/or following word. The intonation curve which is always preserved, even on shorter words, is the final continuation rise of P1 and the final peak of P2.

Besides the prosodic unit-final high boundary tone (the continuation rise of pattern P1 or the final peak of P2), prosodic boundaries manifest themselves through an increased duration of the group-final syllable, compared to the surrounding syllables (e.g., Di Cristo 1975, Vaissière 1980).

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[2]See Delgutte 1978 for an extension of the number of Fo patterns to six by differentiating between prominent and nonprominent, as well as demarcative and nondemarcative patterns.

It is also generally agreed upon that the number of prosodic units tends to decrease as the rate of elocution increases (e.g., Vaissière 1975a:251, 1980:553, 557). This presumably universal characteristic of prosodic systems is accounted for in Nespor and Vogel by a process of restructuring of two lower level units into one higher level unit. As mentioned above, in Selkirk's model no changes in the formal representation are required for different tempos, as degrees of syntactic disjuncture are encoded in the number of silent grid positions between two constituents to which real-time values are assigned for different tempos; and Kaisse does not address the question of prosodic structure, since it is assumed to play no role in defining the domain of phonological rules.

3. Experimental Design

A corpus was constructed so as to illustrate enchaînement consonants compared to initial consonants in seven minimal or near minimal pairs across different types of prosodic boundaries corresponding to different degrees of syntactic disjuncture. Table I illustrates the particular contexts chosen.

Table I
Selected Contexts

Sentence Type	Syntactic Structure	Prosodic Structure
(1)	a modifier and the following head	one prosodic unit
(2)	a modifier and the preceding head	two prosodic units, with possible restructuring at faster speaking rates
(3)	two conjoined phrases	same
(4)-(6)	a subject and the following predicate:	
	-short subject	same
	-longer subject	same
	-long subject	two prosodic units, restructuring unlikely
(7)	a detached phrase and the following clause	same

The full corpus used in the experiment is given in the appendix. It was presented to two native speakers, one male and one female, who were asked to read each sentence type five times at three different tempos (slow, "normal" and fast speech) which were to be determined by the speakers. This resulted in 210 tokens for each speaker (five tokens for each sentence at a given tempo x three tempos x 14 sentence types) which were presented to the subjects in a random order. Recordings took place in a sound treated studio.

The study was restricted to the consonant /r/, because (1) it belongs to the consonants which lengthen any tautosyllabic preceding vowel in French (especially under stress, e.g. Delattre 1951:15ff.), thereby providing evidence about syllable structure; and (2) it has been shown to exhibit a certain amount of phonetic variation depending on its distribution and syllabic position (Borel-Maisonny 1942, Straka 1965, Simon 1968, Rialland 1984).

4. Analysis

Each utterance was analyzed using broad band spectrograms made on a voice Print 700 and examined with respect to the phonetic cues listed in (2) which have been shown to be good indicators of syllabic structure in languages (e.g., Malmberg 1955, Lehiste 1960, Gårding 1967).

(2) a. the phonetic realization of /r/
b. its duration
c. the length of the second formant transitions to the surrounding vowels
d. the duration of the preceding vowels
e. the eventual presence and length of a following pause.

The duration measurements were made from the spectrograms to the nearest 10 msec., based on commonly used spectral cues to determine the boundaries of segments, such as the disappearance of the second formant (and sometimes also the first) and the appearance of a (more or less) pronounced noise pattern in the mid-frequency region to delimit (voiced or voiceless) fricative /r/ from the surrounding vowels. At times, especially in faster speaking rates, the syllable-final sonorant was fully vocalized, distinguishable from the preceding nucleus only by a change in the formant structure and the weakening or disappearance of the upper formants. The quality of the preceding vowel also plays a role: the delimitation was most difficult when syllable-final /r/ followed the vowel /a/ due to their acoustic similarity. Similarly, the intervocalic (initial and linked) sonorant was sometimes, especially in normal and fast rates of articulation, realized as a glide-like segment, separable from the nuclei on either side only on the basis of the changes in the upper formants.

The different realizations of the consonant were tabulated against the scale shown in (3).

(3) a) vocalic segment

b) voiced fricative

c) voiceless fricative

The duration measurements (cues b-d in (2) above) were statistically analyzed, for all sentence types taken together, and each sentence type by itself, for both speakers, as well as for each speaker separately. Means (in msec.) of segment durations, of formant transition lengths, as well as the corresponding standard deviations were calculated. Two-tailed t-tests were performed and probabilities were calculated for differential means between contexts with initial, as opposed to linked /r/, and contexts with initial, as opposed to non-linked /r/ (cf. Fig. 6a-d below).

Furthermore, fundamental frequency tracings of all utterances containing linked /r/'s were obtained using the PDP11 with the Interactive Laboratory System Speech Analysis Package. The Fo contours of these tokens were interpreted in terms of Vaissière's P1 and P2 patterns. Most tokens had been read by the speakers with an unmarked intonation pattern, that is, without emphasis on a particular word, and with unmarked information focus, that is, as answers to the question "What happens/happened?".

In fact, in the contexts occurring in the present study, namely mono- or disyllabic words followed by a vowel-initial word in the next unit, it was not possible in the absence of a pause to distinguish between patterns P1 (i.e. first level prosodic unit) and P2 (i.e. second level unit) on the basis of the gross overall shape alone, since in both the final rise was followed by a lowering. The decision as to whether restructuring took place was based on (1) a comparison of the intonation contours of the various tokens of a particular sentence-type in a given tempo with respect to relative amplitude of Fo variation, (2) a comparison of the pre- and posttonic syllables with the tonic syllable in the different tokens with respect to relative Fo amplitude, and (3) a comparison of the durations of the prosodic unit-final syllable nuclei. Fig. 2 represents the intonation contours of a non-restructured and a restructured token of sentence-type 2. The crucial factor lies in the relative height of the final peak of suivirent which reaches 222Hz in the former, but only 156Hz in the latter. A second, generally less consistent cue is the relative duration of the final syllable, with the tonic syllable of the non-restructured token being 35 msec. longer than the same syllable in the restructured token, in this case nontonic and not prosodic group-final. Only the length of the nucleus measured from spectrograms was taken into account in the actual tabulation of relative final syllable durations. Finally, a third and even less consistent factor is the relative Fo height of pre-, tonic and posttonic syllables which is difficult to interpret due to the segments' instrinsic pitch differences and various microprosodic effects from surrounding

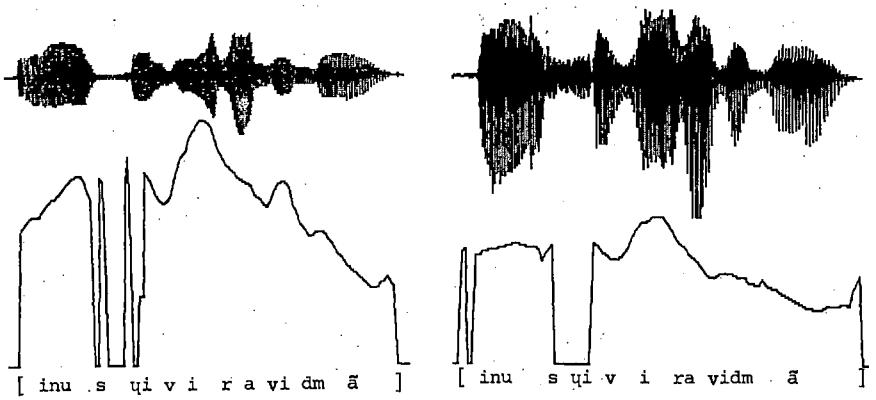

Fig. 2: Wave-form and Fo contour of a nonrestructured (left) and a restructured (right) fast speech token of sentence type 2 (Ils nous suivirent avidement) by the male speaker.

consonants. In the non-restructured token in Fig.2 the pre- and posttonic syllables are much lower in Fo amplitude than the tonic syllable. In the restructured token, the pretonic syllable has a slightly higher Fo than the tonic one, and the Fo of both is higher than the Fo of the posttonic syllable.

5. Results

5.1. Linking

The number of tokens containing linked vs. non-linked consonants was tabulated, based on (1) the absence of a following pause, (2) the absence of any laryngealization in the onset of the following vowel (ever so slight, if present),[3] and (3) the durations of /r/, the preceding vowel, and the formant transitions (see section 5.4. for discussion of exact measurements). Fig. 3 summarizes the count.

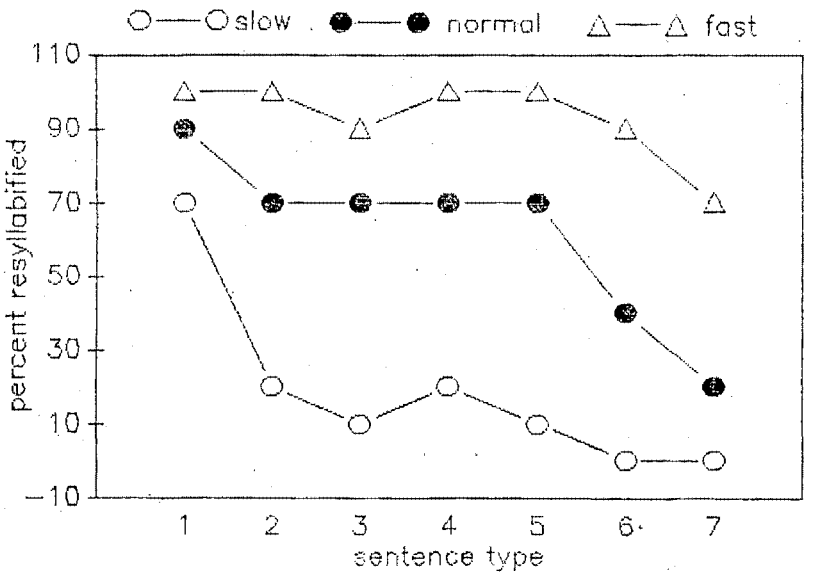

Fig. 3: Percentages of linked /r/'s in each sentence type and tempo.

As the figure suggests, the domain of resyllabification is enlarged with increasing rate of articulation to contexts with a greater degree of syntactic disjuncture. The total percentages for each speed are as follows:

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[3] Interestingly, the corpus contained no occurrence of glottal stop, contrary to Léon's 1971 findings based on an analysis of radio programs, from which he concluded that in this particular speech style at least, this juncture marker tends to be generalized as a syntactic reinforcement at the begining of prosodic phrases.

slow speech 13%, normal speech 43%, fast speech 65%. Enchaînement is considered to have taken place in a particular sentence type, that is, in a particular syntactic and prosodic context, at a given tempo, when at least 70% (i.e. 7 out of 10) of the tokens contain a linked /r/. In slow connected speech, linking only takes place between words standing in close syntactic and prosodic connection (i.e., prosodic unit-internally) such as the head noun and its preceding modifying adjective exemplified in the first sentence type. (The few exceptions are due to some overconscious renditions by the female speaker, possibly influenced by the at times close proximity of the other member of the minimal pair.) At normal rate of speech, linking is extended to some contexts between two prosodic units which, according to Nespor and Vogel, tend to undergo restructuring into a single prosodic phrase in faster tempos. Finally, in fast speech, it applies in all the contexts tested, including across the two breath-groups in sentence types 6 and 7 in which restructuring is said to be highly unlikely (e.g. Nespor and Vogel, 1982:246).

The extension of enchaînement to a successively larger domain with increasing tempo, judged on the basis of the above-mentioned cues is corroborated by other segmental as well as suprasegmental phonetic cues to the occurrence of resyllabification and to the prosodic structure, as discussed below.

5.2. Prosodic Structure

The Fo tracings of all the tokens with linked /r/ determined as outlined above were analyzed in terms of Vaissiere's P1 and P2 patterns. Surprisingly, it was found that prosodic structure does not affect linking which takes place across prosodic units, as well as within, given an appropriate tempo.

Fig.4 gives the count of tokens with linked /r/ in which restructuring can be said to have occurred, based on the absence of a high prosodic unit-final boundary tone. In all but five normal and five fast speech tokens, the tokens where restructuring is said to have taken place on the basis of the Fo contour are also the ones with the shortest final vowel durations on the relevant words. There are no values indicated for sentence type 1, since, excluding three very artificial sounding slow speech tokens by the female speaker in which a pause is inserted between them, the prenominal adjective and the following noun always belong to the same prosodic unit.

As Fig.4 shows, restructuring did not take place at all in slow speech where the sentences (except sentence type 1) were divided by a pause following the relevant word in /r/, and it is still relatively rare at a "normal" rate of speech (14% of all tokens with linked /r/). The few occurrences of restructuring in normal speech are all found in the male speaker's tokens which were generally read at a slightly faster tempo and in a more casual style than the female speaker's renditions.

The more frequent occurrences of restructuring in fast speech (33% of all tokens with linked /r/) seem to have been determined by the syntactic context, by the length of the utterance and of the constituents involved, although here too, tempo and style play a role (it is again the male speaker who restructures more frequently) and so do presumably other factors as well.

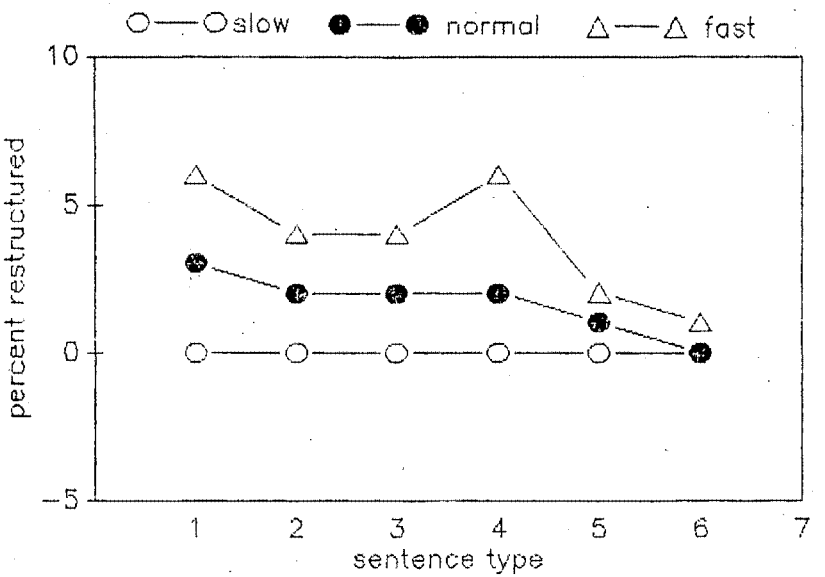

Fig. 4: Incidence of restructuring in tokens with linked /r/ for each sentence type and tempo.

The closer the syntactic context between two words separated by a prosodic phrase boundary, the more likely restructuring is, as shown by the frequency of its occurrence in sentence type 2 between the head verb and its adverbial modifier, or the two members of a conjoined phrase in sentence type 3. Length of utterance seems to be important in two ways. All other things being equal, a very short utterance potentially containing more than one prosodic unit has a greater chance of being restructured than a longer utterance with the same number of prosodic units, as a comparison of sentence types 4 and 6 shows.[4] Given constituents of similar length, such as the noun phrases in sentence types 4 and 5, restructuring is favored if the utterance as a whole is longer, with a major prosodic boundary in close proximity (sort, et in sentence type 5). Furthermore, the occurrence of restructuring in sentence type 7 contradicts the general assumption (e.g., Cinque 1977) that 'detached' phrases (in particular, so-called hanging topics which promote a previously non-topic noun phrase to topic status) are obligatorily set off as a separate prosodic phrase from the rest of the sentence.

Crucially, however, although resyllabification and restructuring are affected by the same types of factors, restructuring itself does not constitute a necessary condition for the application of resyllabification.

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[4] Interestingly enough, in these two sentence types with monosyllabic prosodic group-final words the final high tone was sometimes delayed and realized on the following vowel-initial clitic.

5.3. /r/ Realization

An older oscillographic analysis by Borel-Maisonny 1942 followed by a kymographic study by Straka (e.g., Straka 1965) based on normal to faster rate of articulation reveals two basic variants of French /r/ in terms of manner of articulation. The first one is a very posterior (dorso-velar or uvular) fricative which can be voiced or voiceless depending on contextual factors. It is voiceless following voiceless consonants (e.g., prune, trouver, frise), and voiced following voiced consonants and intervocalically (e.g., brique, gavroche, des roses, arroser). The second one is a vocalized variant found syllable- and word-finally (e.g., perdu, clair), and ocasionally also intervocalically. Furthermore, in syllable- and especially word-final position, /r/ was also found to tend to be reduced to a simple lengthening of the preceding vowel (e.g., lire, munir).

A more recent, radiocinematographic study based on fairly rapid speech by Simon 1967 reveals that /r/ is weakest, in terms of articulatory hold duration and degree of constriction between the back of the tongue and the velum, in prosodic group-, word- and syllable-final position (e.g., au grand bazar, canard, encartage, Marcel, sur les) and in unstressed intervocalic syllable-initial position (e.g., un raglan). It is stronger in stressed intervocalic syllable-initial position (barrage), and strongest in stressed post-consonantal syllable-initial position (e.g., casserole), as well as in word- or prosodic group-initial position (e.g., réponds-moi). In particular, she reports the measurements (in msec.) listed in Table II for the contexts relevant for the present study.

Table II

Measurements (compiled from Simon 1976)

	Group-Initial	Intervocalic stressed	Intervocalic unstressed	Group-Final
articulatory hold duration (in msec.)	60	60	40	40 (often no hold at all)
degree of constriction (diameter in mm.)	10	8.5	10	13

The realizations found in the present corpus only partly support the results of these previous studies. The tabulated phonetic variants of /r/, listed against the acoustic scale described in (3) above, and according to tempo and syllabic position, are given in Fig.5a through c (for a more detailed analysis, see Laeufer, in preparation).

In slow speech the majority of the initial (61%) and final unlinked (57%) realizations of /r/ cluster at the voiceless fricative end. Presumably this articulatorily speaking rather strong realization of final /r/ is due to the monitored and conscious articulation characteristic of slow rate of speech, as well as the position of the consonant under stress,

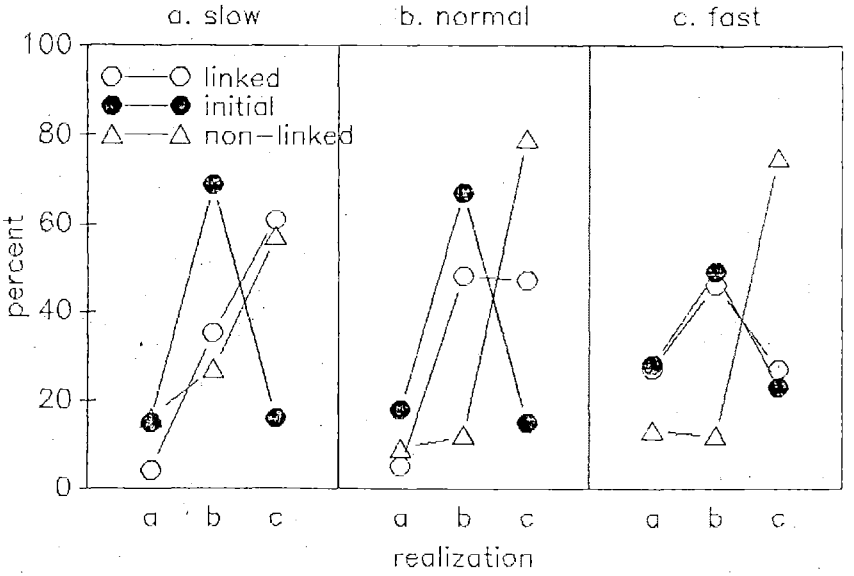

Fig. 5: Initial, linked and nonlinked phonetic variants of /r/ in slow (5a), normal (5b) and fast (5c) speech.

at the end of a prosodic unit before a pause. The few occurrences of vocalized final /r/ (16%) are found in the male speaker's tokens which are read on the average with a slightly more rapid tempo and more casually than the female speaker's. As for the high incidence of initial /r/ as a voiceless fricative (61%) it is explainable by its position under stress in most sentence types. When unstressed, as in sentence type 5 and some realizations of types 1 and 2, it is realized as a voiced fricative.

In normal speech, most of the realizations of initial /r/ are divided almost equally between the voiceless and the voiced fricative pronunciations (47 and 48% respectively). The latter pronunciation is characteristic of the male speaker's renditions and the former of the female speaker's. Most realizations of unlinked final /r/ (79%), on the other hand, are voiceless, and belong to the female speaker's renditions which, as noted above, were read at a slower pace and more consciously articulated than the male speaker's.

In fast speech, on the other hand, there is a clear difference between intervocalic syllable-initial /r/ the articulation of which tends to be located at the "voiced" end of the scale, with 46% of voiced fricative and 27% of vocalized realizations, and the few occurrences of final /r/ (again belonging to the female speaker's tokens) most which are still fairly strongly articulated (75% have voiceless realizations), as opposed to the "weak" pronunciation of prosodic group-final /r/ in fairly rapid speech reported in Simon 1967 and described above.

Linked /r/, on the other hand, is mostly realized as a voiced fricative in slow speech (69%), which is not surprising given the fact that in this tempo, linking occurs most often before an unstressed syllable (sentence types 1 through 5, see Fig. 3 above). The same holds for normal speech, with 67% of voiced fricative realizations. In fast speech, initial and linked /r/ follow roughly the same pattern as far as their realizations are concerned. The patterns are almost superposed, with a majority of voiced fricative realizations.

5.4. Discussion of the Durations

Fig. 6 summarizes the results of the statistical analysis of the duration of (1) the consonant, (2) the preceding vowel (henceforth V1), and (3) the length of the second formant transitions leading out of and into the vowels on either side of /r/ (henceforth FV1 for the transitions from the preceding vowel and FV2 for the transitions to the following vowel). Initial stands for being in the context of syllable-initial /r/ in sentence types (1b) through (7b). Linked and nonlinked stand for, respectively, the contexts of linked and non-linked final /r/ in sentence types (1a) through (7a). The values on the Y-axes represent the means of the durations for all tokens (in msec.).[5] Due to the important effect of stress on vowel duration in French, particularly in the presence of a lengthening consonant, only sentence types 1, 2, and 5, with minimal pairs of sentences which are identical in terms of stress, were taken into account to calculate V1 and FV1 duration. In sentence type 1, V1 is unstressed both before initial and linked /r/; in sentence types 2 and 5 , V1 is stressed before both types of /r/'s, except for the tokens with prosodic restructuring, in which it is unstressed.

5.4.1. Initial versus non-linked final /r/

One cannot fail to notice the remarkable similarity of the patterns across the different graphs. As expected, the mean durations generally decrease from slower to faster speech due to the general compression of segments in time caused by an increasing speaking rate. As also expected, mean V1 and FV1 durations in both slow and normal speech are significantly greater before an unlinked syllable-final consonant than before an initial hetero-syllabic consonant (in fast speech, all tokens of sentence types 1, 2, and 5 contained linked /r/'s). In slower speech, the difference in the duration of V1 in sentence types 2 and 5, in which the prosodic unit-final syllable is stressed, is close to 80% (mean difference = 120.74, T-stat. = -9.404, Prob. = 0.0001). O'Shaughnessy 1981 estimates it at 130% for monosyllabic words in isolation, and Rialland 1984 at around 80% for /a/ in the pair le bar trouvé 'the discovered bar' vs. le bas r' trouvé 'the rediscovered stocking'. In normal speech the difference is 47% (mean difference = 30.50, T-Stat. = -3.074, Prob. = 0.036). The difference in V1

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[5] There were some missing values due to (especially slow speech) pronunciations by the female speaker of some N forms with a final schwa (often heard as a strong vocalic release), in particular in bars 'bars' [ba:rə], Pierre 'Peter' [pjɛ:rə], suivirent 'followed' [sɥivi:rə]. Missing formant transition values are due to an impossibility at times to clearly locate and measure the transitions, often due to the lack of a clear steady state in /r/ and/or in the surrounding vowels.

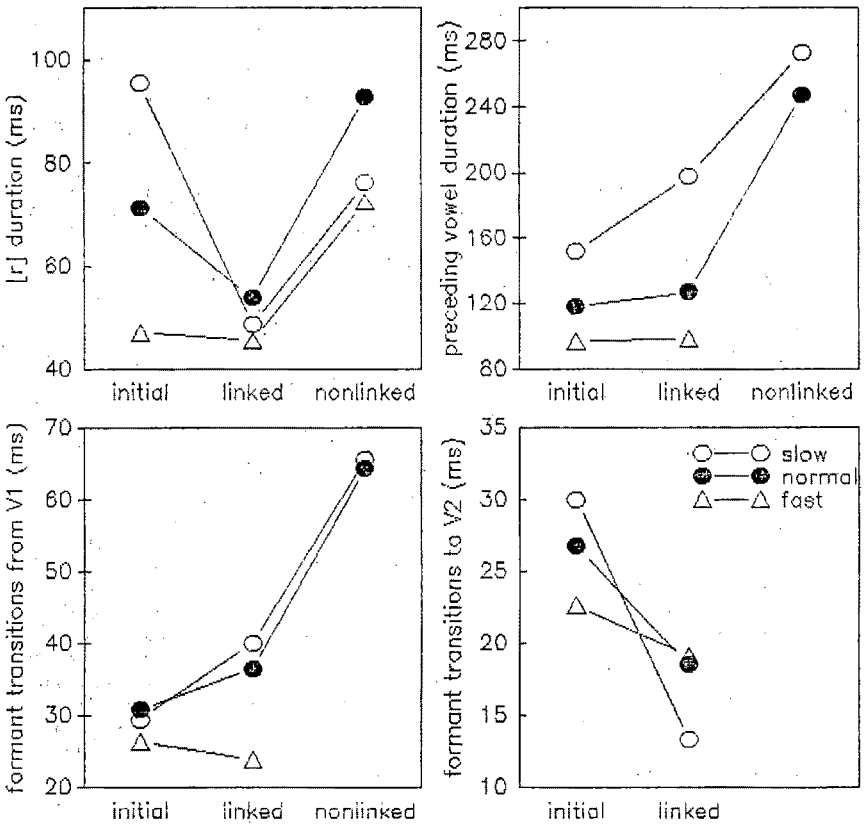

Fig. 6: Duration measurements (in ms) in initial, linked, and non-linked position for each tempo.

duration, although less pronounced, is statistically significant even in sentence type 1, where the final syllables of premier [pʀamje] 'first, masc.', premiere [pʀamjɛ:r] 'first, fem.' are unstressed, that is not followed by a high boundary tone: e.g., slow speech mean I = 151.00 (St.dev. = 27.16), mean N = 215.71 (St.dev. = 60.03), T-stat. = -2.668, Prob. = 0.0294.

The significant difference in the duration of FV1 is in accordance with the results of other studies which have revealed a correlation between length of formant transitions and syllabic structure (cf., e.g., Malmberg's 1955 speech synthesis experiment which revealed that for a sequence 'aga' to be percieved as 'ag-a', the necessary conditions are (1) significantly longer formant transitions from V1 to the consonant, and (2) the presence of a stop closure no shorter than 40 msec.).

The statistically significant greater duration of syllable-initial (mean = 95.43, St.dev. = 34.12), as opposed to syllable-final unlinked /r/ (mean = 76.24, St.dev. = 27.34) in slow speech (difference of means = 19.19, T-Stat = 1.718, Prob. = 0.109), is presumably ascribable to the difference in syllabic position. It confirms the results of previous, radiocinematographic (Simon 1967) and spectrographic (Rialland 1984) studies in which it was found that in French, consonants are "stronger" (one of the phonetic correlates of which is precisely increased duration) in syllable onsets than in codas. Stress, on the other hand, presumably plays no role in the difference in /r/ duration, since all tokens of syllable-final /r/ occured under stress (at the end of a prosodic unit, as determined by the presence of a pause and a high boundary tone), and similarly, most tokens of syllable-initial /r/ are stressed in slow speech, in particular in sentence types 3, 4, 6 and 7. Rapidement 'quickly' in sentence type 2 has either secondary initial stress or emphatic stress, and so does raccord 'repair' in sentence type 1. The only unstressed tokens of initial /r/ occur in hareng 'herring' in sentence type 5, which is destressed due to the presence of an immediately following stress, its stress being shifted onto the preceding syllable: ha'reng 'saur -> 'hareng 'saur (see e.g. Verluyten 1982, Dell 1984 for a discussion of stress retraction in French).

In normal and fast speech,[6] on the other hand, although the difference in the duration of /r/ is also statistically significant, /r/ turns out to be longer in syllable-final position (normal speech mean = 92.88, St.dev. = 23.59), fast speech mean = 72.50, St.dev. = 12.58) than in initial position (normal speech mean = 71.45, St. dev. = 30.84; fast speech mean = 47.14, St.dev. = 15.17), which is the opposite of the values for /r/ in slow speech. As mentioned, previous studies on the correlation between consonant duration and syllabic position lead one to expect initial /r/ to be longer than final /r/, all other things being equal. In the present study, all other relevant things are equal in slow speech, since both types of /r/'s occur in a stressed syllable which is also prosodic group-final. In normal and fast speech, however, final /r/'s are still stressed and group-final, a position which is presumably least affected by the compression of segments due to the increase in tempo, whereas initial /r/'s are stressed and occur in the group-final syllable only in the tokens in which prosodic restructuring did not take place.

3.4.2. Initial versus Linked /r/

3.4.2.1. Slow Speech

At first glance, the slow speech results seem contrary to the ones expected if linking in French corresponds to total resyllabification as is generally claimed (e.g., Delattre 1951:67). However, upon a closer examination, the results turn out to be, on the contrary, very interesting and remarkably consistent. What they in fact suggest is that in slower speech, linking does not correspond to total resyllabification whereby the

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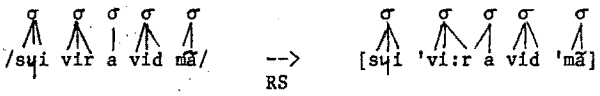
[6] It is doubtful that the sample means of the few observations of unlinked consonants in fast speech (5 observations, compared to 70 for initial /r/), represent the true means of the population. For the sake of the argument, we will however assume that they do come close.

consonant in question changes its affiliation from the preceding to the following syllable. Instead only partial resyllabification takes place: the consonant is associated with the following syllable, without, however, giving up its affiliation with the preceding syllable. The result is an ambisyllabic segment which belongs concurrently to both syllables. The process is shown in (4), where ' represents stress and RS stands for resyllabification.

(4) Initial syllabification Slow speech syllabification



Supposing this to represent the facts, we would expect (1) the preceding vowel to be significantly longer before linked than before initial /r/, since the former is still tautosyllabic with the lengthening consonant, and (2) the formant transitions leading to V1 to be significantly longer before a linked consonant which occurs in the same syllable than before an initial consonant which occurs in the next syllable or word. Both of these expectations turn out in fact to be true for the three sentence types considered for V1 and FV1 duration measurements: difference of mean V1 durations = 45.46 (T-stat. = -1.926, Prob. = 0.077), difference of mean FV1 durations = 16.67 (T-stat. = 2.017, Prob. = 0,049). This is further supported by a difference in the realization of linked, as opposed to initial /r/. As was noted in section 5.3. above, the majority of the former's realizations are voiced fricatives whereas the latter's are voiceless (see Fig.5a). It is in line with characterizations of ambisyllabic segments as articulatorily as well as functionally "weak" segments, as witnessed by the contextual/assimilatory weakening they tend to undergo, especially in unstressed intervocalic context : cf., for instance, the flapping of ambisyllabic /t/ in American English lattitude, later, latter, etc.

The statistically significant difference in /r/ durations, as well as in the length of the formant transitions towards V2, with initial /r/ being significantly longer, and FV2 being significantly longer after initial /r/, is presumably due to stress. In most sentence types, initial /r/ and the following vowel are prosodic-group final in slow speech (cf. déstructurer, barons, Thierry in respectively 3, 4/6, and 7), whereas linked ambisyllabic /r/ is partly stressed (the final portion) and partly unstressed (the initial portion), and the following vowel is unstressed (structures et, bars ont, vieillard en).

Interestingly enough, there exists an older oscillographic study by M. Durand (1936) which compares masculine (i.e. liaison) and feminine (i.e. enchaînement) consonants in adjective-noun pairs like mauvais état [movɛzeta] 'bad state', mauvaise épée [movɛzepe] 'bad sword', or petit orage [pətitɔraz] 'small storm', petite orange [pətitɔrăž] with respect to oral air pressure and glottal tension. Although Durand herself cautions against extrapolating too much from her experimental results, she does conclude, based on the decrease of pressure on the feminine enchaînement consonant that it might retain some of its "implosive", that is, syllable-final, nature. In other words, she seems to suggest that it might be

ambisyllabic, as opposed to the masculine liaison consonant, the increasing pressure of which suggests that it is truly initial. Cf. also Boudreault's (1868:45) observation that enchaînement consonants, especially sonorants, are strongly coarticulated with the preceding vowel, although perceptually, one has the feeling that they also partly belong to the following vowel.

5.4.2.2. Fast Speech

In fast speech, the difference in duration between initial (mean = 47.14, St.dev. = 15.17) and linked /r/ (mean = 45.46, St.dev. = 13.74) falls within the measurement range of error and is thus not statistically significant (difference of the mean = 1.68, T-Stat.= 0.673, Prob. = 0.502), both taken globally, (i.e. all sentence types together) and separately (i.e. each sentence type by itself). The results agree with the ones reported in Delattre 1981 who compared, among other things, word-final and word-initial /n,l,s/ in pairs like la masse agrée vs. le mât sacré, la ville imite vs. la vie limite, une avale vs. l'u nasale, etc. He notes that linking and initial consonants prove to be practically of equal length (final /n,l,s/ were 82, 76 and 135 msec.; initial ones 82, 74 and 134 msec., respectively).

Furthermore, the realizations of initial and linked /r/ are very similar, as Fig. 5c above suggests: both variants have a majority of voiced fricative realizations.

The difference in duration of the preceding vowel is likewise not statistically significant: I mean = 96.92, St.dev. = 28.73; L mean = 98.50, St.dev. = 29.93; T-Stat. = 0.312, Prob. = 0.756.

The formant transitions leading from initial /r/ to the preceding vowel (mean = 26.39, St.dev. = 11.30) are not significantly different from the ones leading from linked /r/ to that vowel (mean = 23.88, St.dev. = 9.91; difference of means = -2.51, T-Stat.= 1.288, Prob. = 0.2004). This is true globally for sentence types 1, 2 and 5, and when each of these sentence types is taken separately. Likewise, there is no difference in the formant transitions leading from initial and linked /r/ to the following vowel.

Furthermore, a comparison of the length of the transitions leading to V2 with the ones leading to V1 proves them to be very similar in duration (the difference of the means is 3.75 msec. in the case of initial consonants and 4.71 msec. in the case of linked consonants, which lies well within the range of error).

Combined, these five phonetic cues suggest therefore that in fast speech initial and linked /r/ are identical in terms of syllabic structure. In other words, linking corresponds to total resyllabification which can be represented as shown in (5).

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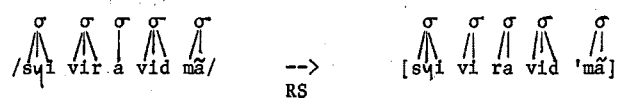
[7]The results were not unambiguously clear, due in part to the experimental conditions, namely the inconvenience to the subjects brought about by the complicated and elaborate machinery.

(5) Initial syllabification Fast speech syllabification



With the association of the consonant with the following syllable there is a concomitant dissociation from its original syllable, which is in accordance with the generally made claim about French linking (e.g., Delattre 1951:67).

5.4.2.3. Normal Rate of Speech

In "normal" tempo, on the other hand, the global results are somewhat mixed, due to more pronounced inter-speaker variation in tempo and style. The male speaker's renditions are noticeably faster and more casual than the female speaker's whose pronunciation is more monitored and therefore also slower. It is thus useful to examine, in addition to the global results given in Fig. 6 above, the tokens of each speaker separately. These are represented in Fig. 7.

The difference in the duration of /r/ (with linked /r/ being on the average 18 msec. shorter than initial /r/) shows up as statistically significant when the results are considered globally. Considered separately, however, the difference in /r/ duration is significant only for the female speaker, whereas the male speaker's initial /r/'s are not significantly different from his linked /r/'s (Fig. 7a).

An inter-speaker difference is also noticeable in the realization of /r/. As noted in section 5.3. above, most unlinked stronger final /r/'s are due to the female speaker's slower and more monitored renditions, whereas linked /r/'s are primarily found in the male speaker's tokens with a majority of voiced fricative realizations similar to the unstressed initial /r/ renditions.

The difference in the duration of the preceding vowel, as well as in the length of the formant transitions towards V1 is not statistically significant globally in all seven sentence types taken together, as well as in sentence types 1, 2, 3 and 5 taken separately. As for the remaining three sentence types, either the difference in the duration of V1 is significant (sentence type 4 and 7, with only two observations before linking /r/ for the latter), or it is the length of the formant transitions towards V1 (sentence type 6). Taken separately, however, the V1 duration results for each speaker are as shown in Fig. 7b. Again, the difference in the means is statistically significant for the female speaker's tokens only. Similarly, for the formant transitions towards V1 which are shown in Fig. 7c.

The difference in the duration of the formant transitions towards V2 turns out to be statistically significant globally, as well as for each speaker separately, with the formant transitions following initial /r/ longer than the ones following linked /r/. It is however valid only for sentence types 3, 4, 6 and 7, where it is obviously again attributable to the presence of stress and a following prosodic group boundary in most

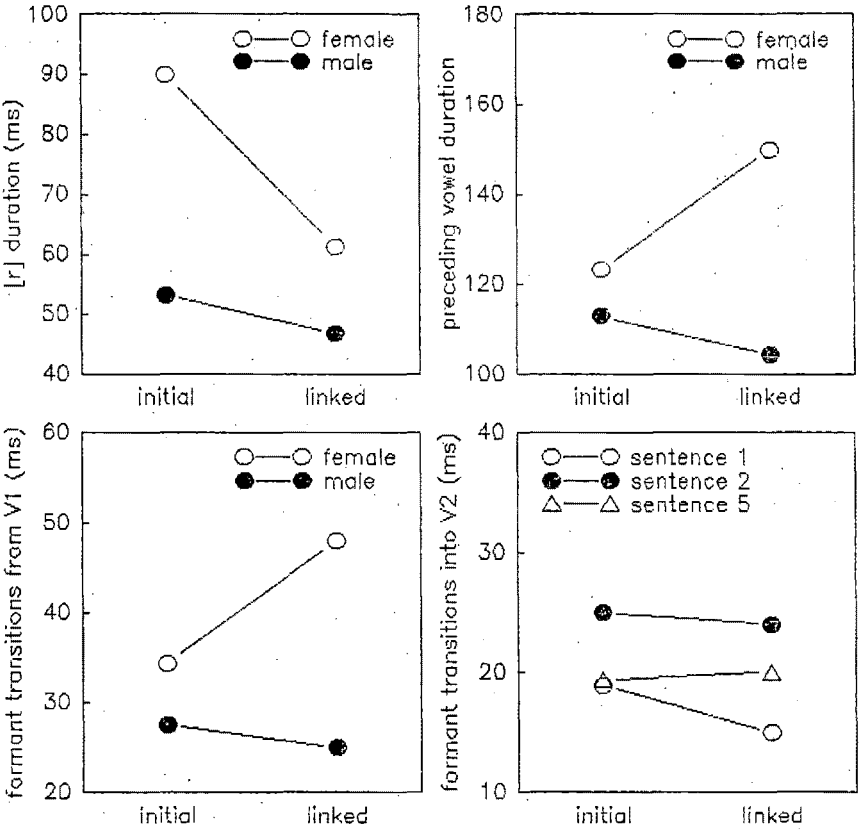


Fig. 7: Duration measurements at normal rate of speech for each speaker in initial and linked context.

tokens with initial /r/. In sentence types 1, 2, and 5, on the other hand, there is no difference in stress in the vowels following initial and linked /r/, and the difference in the duration is not statistically significant (Fig. 7d).

Finally, notice that a global comparison of the length of the formant transitions leading to the following vowel with the ones leading to the preceding vowel reveals them to be relatively similar. In the case of initial /r/ the difference amounts to 4 msec. which is well within the range of error. In the case of linked /r/ the difference is 18 msec. which exceeds the range of error. An examination of the values for each speaker separately, however, reveals this to be due to the female speaker whose transitions towards V1 exceed the ones towards V2 by 27 msec. In the male subject's renditions, on the other hand, the transitions to both vowels have quasi-equal lengths as shown in Table III.

Table III

Mean Duration of Formant Transitions (in msec.)

		FV1	FV2	FV1-FV2
F	I	34.33	27.61	6.72
	L	45.91	19.20	26.71
M	I	27.50	30.12	-2.62
	L	27.04	17.90	9.14

It is interesting to compare these results with the ones from Delattre's (1965:36ff.) investigation, by means of spectrograms and speech synthesis of so-called "internal juncture" and its perception in normal rate of speech of English, German, French and Spanish phrases of the type an ice man vs. a nice man, zum einen 'for one' vs. zu meinen 'to mean', du nôtre 'of ours' vs. d'une autre 'of another', en ojo 'an eye' vs. enojo 'anger'. He found that the main factor corresponding to a difference in syllabification between the four languages lies in "the degrees of arresting and releasing" of the formant transitions preceding and following the consonant closure, and reflecting, respectively, the closing and opening of the articulators. English and German showed maximally arresting consonant transitions before the closure standing in a three to one ratio with the releasing transitions, which is perceived as closed syllabification. In Spanish, the arresting and releasing transitions proved to be somewhat equal, and in French, the arresting transitions turned out to be very weak (up to one third of the releasing ones), and the releasing transitions maximal. The Spanish and the French state of affairs are both perceived as open syllabification. Hence, contrary to English and German, internal juncture is not distinctive in Spanish and French. In the present study, the comparison of the length of the transitions to either vowel resembles more Delattre's results from Spanish than his results from French, although the implications with respect to syllabification are the same.

The overall results in normal speech for each speaker separately are summarized in Table IV , where + stands for statistically significant and - for not significant.

Table IV

Statistical Significance of the Difference in the Duration Means for each Speaker

	Speaker F	Speaker M
1) /r/	+	-
2) V1	+	-
3) VF1	+	-
4) VF2	-	-

As Table IV shows, the results for the female speaker are very similar to the results for slow speech. The statistical significance of the difference in the duration of /r/, V1 and in the length of the formant transitions towards V1 suggest that she preserved the same syllabic structure for linked /r/ in normal speaking rate as she had in slow speech: linking amounts to partial resyllabification of the consonant with the following vowel, with preservation of the affiliation with the preceding vowel. The male speaker's renditions, on the other hand, suggest that his linked /r/'s undergo total resyllabification, that is, dissociation from the preceding vowel and exclusive reassociation with the following vowel, which is similar to the results from fast speech discussed above.

The difference in tempo between the two speakers, signaled by a difference in the incidence of restructuring (cf. section 5.2. above), in the different lengths of the pauses between unlinked /r/ and following initial vowels (mean F = 326.00, mean M = 204.52), and in a difference in the compression of segments in faster rates of articulation, thus manifests itself also in a difference in phrasal syllabification.

6. Conclusion

Based on a bottom limit of at least 70%, linking can be said to occur in slow speech only within a prosodic unit, across the weakest type of syntactic boundary (represented in Nespor and Vogel 1982 as accentual phrase-internal contexts, and in Selkirk 1984 by a single silent grid position, as opposed to more loosely connected words, separated by prosodic boundaries in the former, and two or more silent grid positions in the latter). Crucially, in slow speech linking corresponds only to partial resyllabification, which leads to ambisyllabic, rather than fully initial linking consonants, as witnessed in particular by the duration of the preceding vowel and the formant transitions leading to it. As speaking rate increases, enchainement is extended to successively greater domains and corresponds to total resyllabification. More specifically, it is extended in normal speech to contexts with two, three and even one sentence type with four silent grid positions between the focus and the determinant words. And in fast speech it applies in all contexts tested, including across non-restructured breath-groups with five and possibly more silent grid positions between them.

Hence only the model outlined in Selkirk 1984 makes the right predictions, namely, that (1) with increasing rate of speech, the domain of the rule becomes larger, irrespective of prosodic structure, and (2) there exists a specific degree of disjuncture beyond which the rule does not apply in a given tempo.

Kaisse's model, on the other hand, does not correctly represent the facts of French enchaînement. According to this model, the rule belongs to so-called fast speech rules and should, therefore, not apply at all in slow speech, but take place across the board in normal and particularly in faster speech, irrespective of syntactic and prosodic structure.

Nor does the model proposed in Nespor and Vogel 1982 correctly represent the facts, since the domain is predicted to remain constant across different speaking rates, except for cases of restructuring which combine two prosodic units into one. As described in section 5.2. above,

such restructuring took place only in a relatively small number of tokens with linked /r/, and it does not represent a conditioning factor for the application of resyllabification.

The study thus provides evidence that, at least in French, resyllabification belongs to the phonological rules proper, and not to the rules for defining (post-lexical) phonological representation, that is, the syntax-phonology mapping rules. Like purely phrasal phonological rules, it is determined by the syntactic timing (that is, the rhythmic structure) of the utterance, and thus applies to a phonological representation fully defined. A comparison with phrasal resylabification rules in other languages is however needed before any generalizations can be made.

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Appendix

Corpus used in the experiment

1 a. Nous avons atteint la premiere accore à midi.
'We reached the first reef at noon.'

b. Nous avons fini le premier raccord à midi.
'We finished the first splicing at noon.'

2 a. Ils nous suivirent avidement.
'They followed us eagerly.'

b. Il nous suivit rapidement.
'He followed us quickly.'

3 a. Il faut des structures et des phrases, pour pouvoir se faire une opinion.
'Structures and phrases are needed to be able to form an opinion.'

b. Il faut déstructurer des phrases, pour pouvoir se faire une opinion.
'It is necessary to unstructure phrases in order to be able to form an opinion.'

4 a. Les bars ont perdu des clients.
'The bars have lost clients.'

b. Les barons perdaient des clients.
'The barons were losing clients.'

5 a. Un vieillard en sort, et beaucoup plus tard, une femme.
'An old man comes out (of it), and much later, a woman.

b. Un vieil hareng saur est bien meilleur mariné.
'An old sour herring is much better marinated.'

6 a. Et tous les nouveaux bars ont perdu des clients.
'And all the new bars have lost clients.'

b. Et tous les nouveaux barons perdaient des clients.
'And all the new barons were losing clients.'

7 a. Quant a Jean-Pierre, Irene ne l'a pas vu.
'As for Jean-Pierre, Irene has not seen him.'

b. Quant a Thierry, Reine ne l'a pas vu.
'As for Thierry, Reine has not seen him.'